A Linac-Ring Option for eRHIC

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Luminosity

$$L = \frac{c}{l}\frac{10^{-4}A}{Zr_p}\frac{N_i\gamma_i\xi_i}{\beta_i^*}F\left(\frac{\sigma_i}{\beta_e^*}\right)$$

$$F(\zeta) := \frac{2}{\sqrt{\pi}}\cdot\int_0^{10}\frac{\exp\left(-s^2\right)}{1+\zeta^2\cdot s^2}\,ds$$

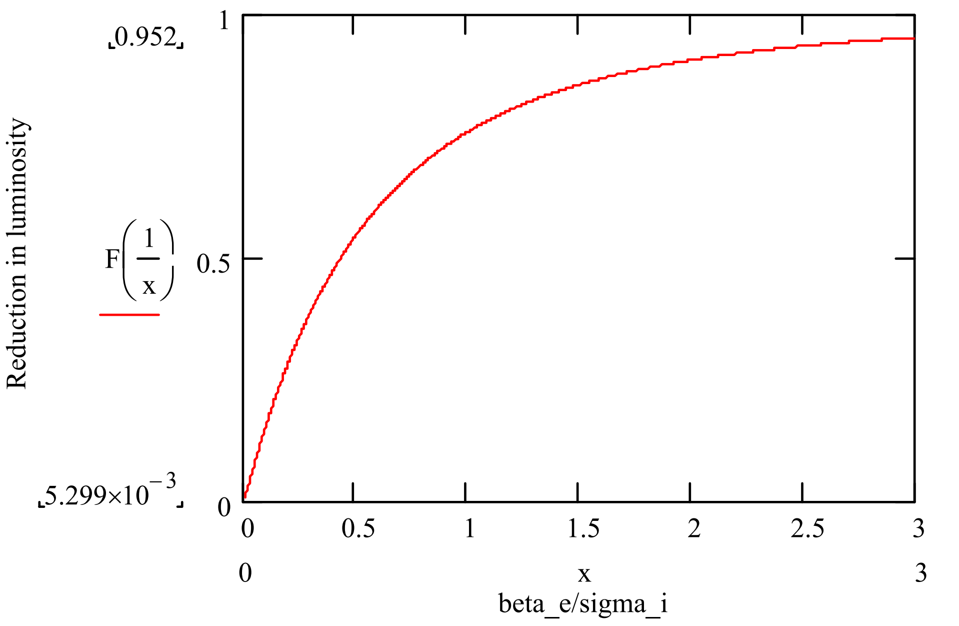
,

$\beta^*{}_e = 0.5$ m

$$\xi_e = \frac{N_i Z r_e}{4\pi\varepsilon_e\gamma_e}$$

$$N_e = \frac{4\pi A\xi_i\varepsilon_i\gamma_i}{Zr_p}$$

$$\varepsilon_e = \varepsilon_i\frac{\beta_i^*}{\beta_e^*}$$



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Linac-Ring Luminosity @ 5GeV

Parameter	Protons (A=1, Z=1, γ=266)				Gold (A=197, Z=79, γ=106)			
N_i (10^9)	Present, 100		Upgrade, 200		Present, 1		Upgrade, 2	
ε_n(rms, μ)	1.4	0.7	1.4	0.7	1.4	0.7	1.4	0.7
β^*_i	0.5	0.3	0.5	0.3	0.5	0.3	0.5	0.3
L (10^{33})	0.460	0.760	0.910	1.500	0.0046	0.0076	0.0091	0.015
Resulting electron linac parameters								
N_e (10^9)	57	29	57	29	140	71	140	71
I_e (A)	0.26	0.13	0.26	0.13	0.64	0.32	0.64	0.32
ε_n(rms, μ)	51	15	51	15	130	39	130	39
ξ_e	0.44	1.5	0.87	2.9	0.14	0.46	0.28	0.92

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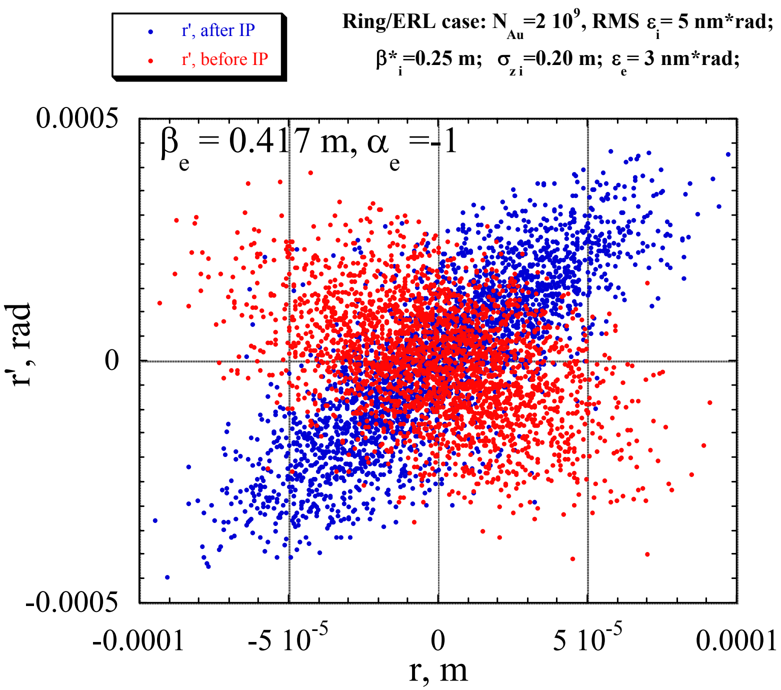
Beam-Beam Interaction



Round electron beam from ERL with initial transverse RMS emittance of 3 nm*rad passes through the IP with the disruption parameter 3.61 (tune shift $\Delta\nu e$ = 0.6). The figure shows Poincare plots for e-beam distribution before (red) and after (blue) the IP. After removal of r-r' correlations, the emittance growth is 11%, a value that should be easily acceptable for energy recovery in the linac.

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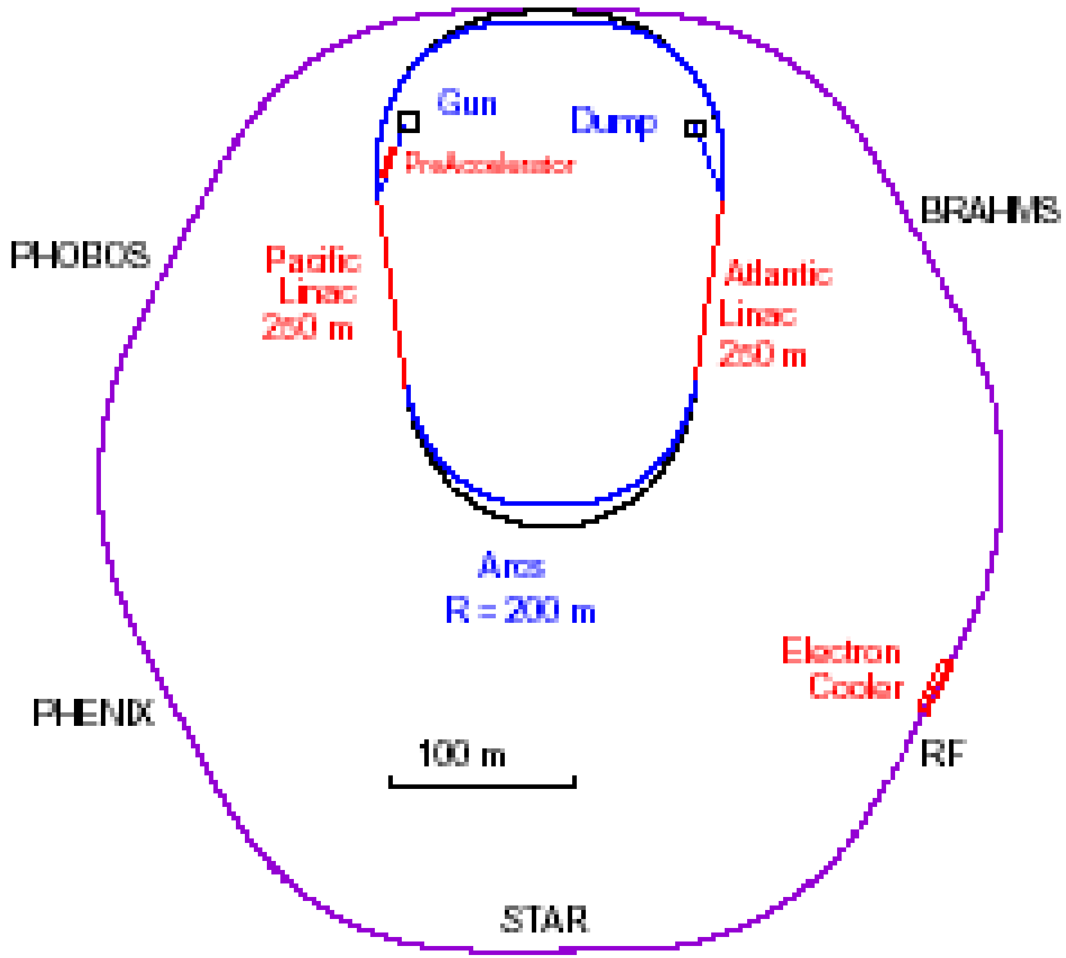
Why?

- • The linac-ring will have a higher luminosity that a ring-ring collider, due to its beam-beam parameter.
- • The electrons are used only once, eliminating spin rotators near the IP.
- • A linac can operate over a wide energy range without sacrificing performance.
- • The polarization of a linac is high and can be rapidly alternated at will.
- • The linac's naturally round beam is well matched to the RHIC beam.
- • With strong cooling of RHIC, the electron current of the linac will be significantly smaller, reducing synchrotron radiation in the detectors.
- • The total electric consumption of the linac is significantly smaller, even if one assumes that its refrigeration does not take advantage of the RHIC refrigerator.
- • A linac can be easily upgraded for higher energies.
- • Just another storage ring is boring!

Layout



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Costs (Jan van der Laan)

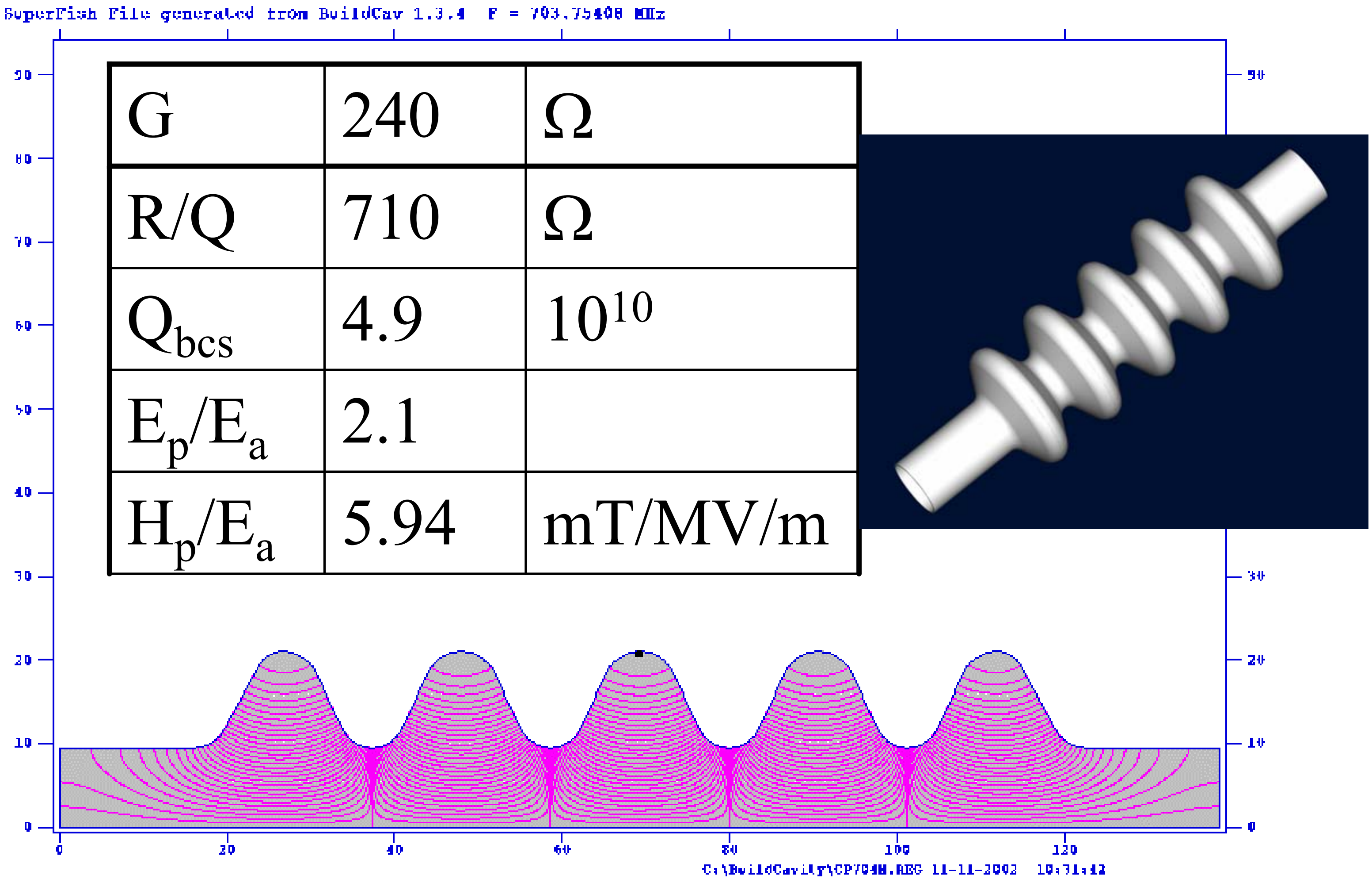
• SRF	\$ 134 M
• Magnets	\$ 30 M
• Tunnel	\$ 17 M
• Vacuum	\$ 10 M
• I & C	\$ 10 M
• Miscellaneous	\$ 6 M
• Gun	\$ 3 M
• Sum	\$ 210 M
• Power	- \$ 45 M
• Sum	\$ 145 M

Superconducting cavities for high average current linacs

- The RHIC electron cooler requires an SRF linac cavity designed for $\beta=1$, high average current ($\geq$100 mA).
- The electron cooling group is in the process of designing such cavity.
- This cavity can also be used for a linac-ring option of eRHIC

5 cell 703.75 MHz Design

G	240	Ω
R/Q	710	Ω
Q_{bcs}	4.9	10^{10}
E_p/E_a	2.1	
H_p/E_a	5.94	mT/MV/m



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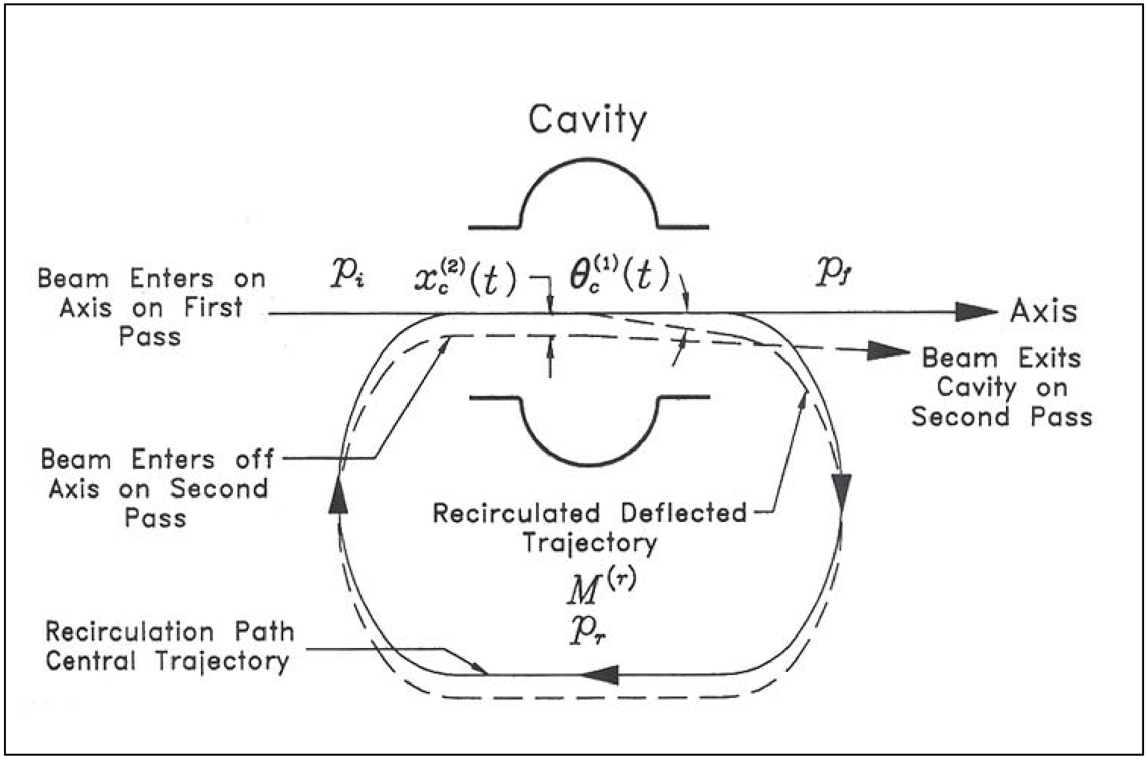
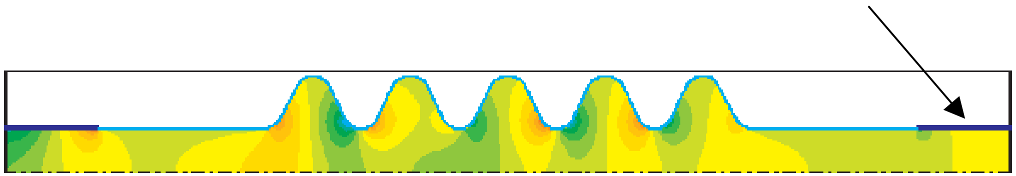
Beam breakup

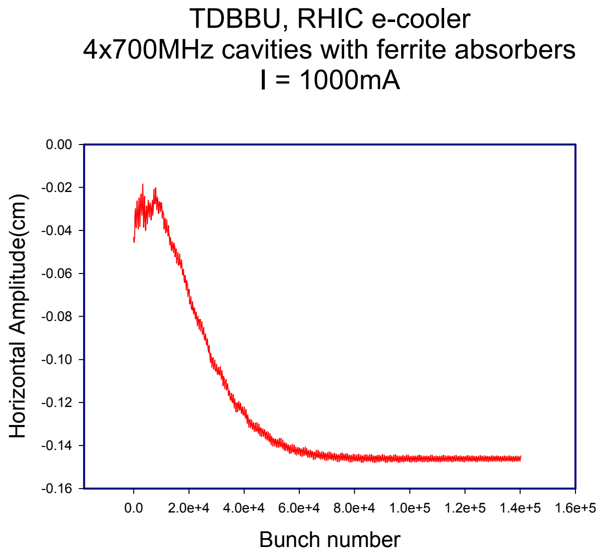


Courtesy:
Geoffrey Krafft

Energy Recovery Linac – beam breakup threshold by TDBBU



Electromagnetic modes calculations and beam break-up



1 ampere!

0.1 second

Dong Wang – **see TPAB046**

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Approximate loss factors

Approximate loss-factor: $$k_l = \frac{\Gamma(.25) Z_0 c}{4\pi^{2.5} a} \sqrt{\frac{d}{\sigma}} \sqrt{N_c}$$

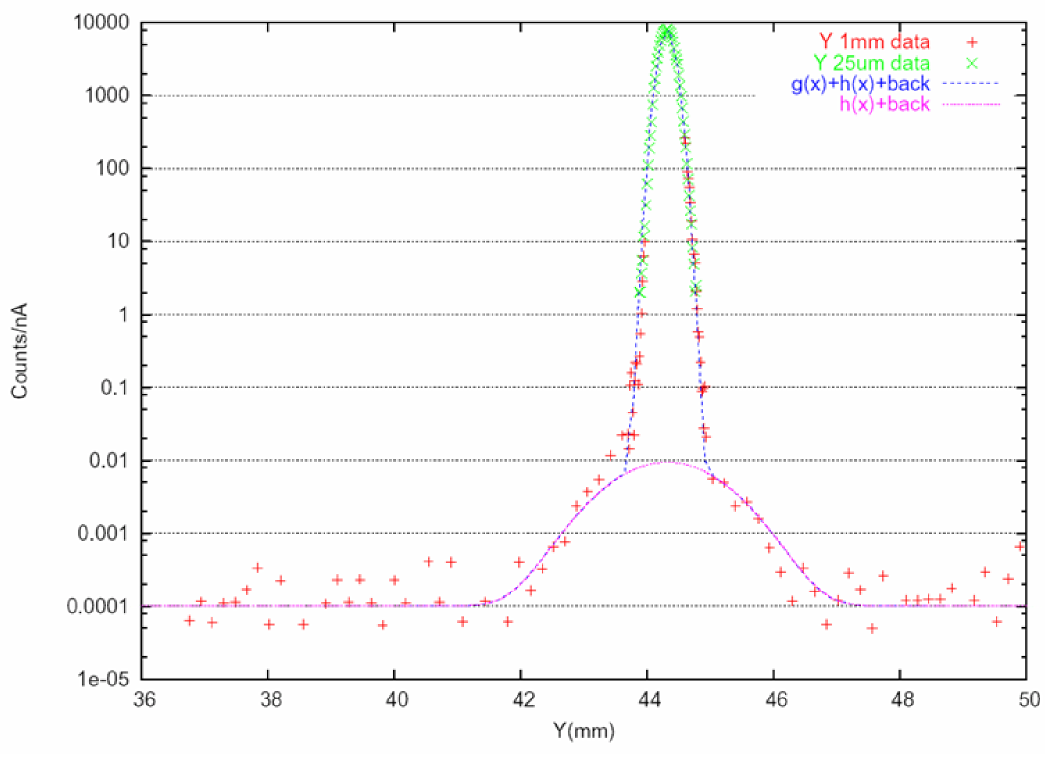
Given $6x10^{10}$ electrons per bunch, σ=1.4 mm / 2.7 mm, bunch repetition frequency 28.2 MHz and ERL mode. ABCI calculation of loss factor by Dong Wang.

Cavity (single)	TESLA 1.3 GHz	New 0.7 GHz
K_l (V/pC)	7.8	1.2
Power (kW)	39.6	6.6
Energy spread	$30x10^{-4}$	$5x10^{-4}$

To do

- Lattice
- Polarized Gun with 300 mA
- Positrons (forget about it)
- Halo
- Magnetized Beam for 4 T Detector Field

Halo measurements Upstream of CEBAF Large Acceptance Spectrometer



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